LINKING CONSTRUCTION INFORMATION THROUGH VR USING AN OBJECT ORIENTED ENVIRONMENT

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The fields of virtual reality and object orientation are evolving rapidly. In the last few years, many firms in the construction sector, in the UK and world-wide, started to link their databases into VR environments in order to offer superior marketing and processing capabilities. The use of an integrated object oriented database is, however, still of limited use. The industry is willing to invest in this technology provided that better information interfaces are provided. This paper responds to this need by developing a VRML (Virtual reality modelling language interface) based interface to an integrated object oriented database which can support the design, planning and estimating of buildings. The database is implemented in Object Store where the information is stored and retrieved from. The user does not need to understand the structure of information within the database. Instead, he/she interacts with a VR model that is generated from the database. Queries that are used to interact with the model are performed within the VR interface. The user can click on a wall and retrieve information about it in terms of texture, cost and time. Such information is stored in the Object Store database. As VRML is a web-based standard, information can then be retrieved remotely from the database over the Internet. This provides a new dimension to construction firms that tend to work in various geographical locations.

This paper describes the VRML-based interface and discusses the potential benefits of linking VR and object oriented databases. Case examples generated from the implemented prototype application will be used to illustrate the developed approach. In particular, cases related to visual cost estimation and planning will be included in order to demonstrate the benefits VR can offer to the construction management domain. The prototype demonstrator presented in this paper has been developed through a series of workshops attended by the industrial collaborators of the research project who specified the requirements of such a prototype.

Keywords: integration, object orientation,VR, VRML.

INTRODUCTION

The opportunities VR and object orientation can offer to many industries in the UK have been well documented by Powell (1995a, 1995b). Recent work in the application of VR in construction includes that of Jones and Webb (1997) and Ha (1997). Jones and Webb developed an open VR system that allows for better communication across the various participants of a construction project. Three demonstrators have been developed as part of this work which support activities such as contractor briefing, environmental impact and acoustic modelling. VRML (Virtual Reality Modelling Langauge) standard was used to implement these demonstrators. This has resulted in a relatively cheap web-based open system which can allow many participants in the construction sector to benefit from such work. However, it has to be said that this

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Aouad, G F, Child, T, Brandon, P S and Sarshar, M (1998) Linking construction information through VR using an object oriented environment. *In:* Hughes, W (Ed.), *14th Annual ARCOM Conference*, 9-11 September 1998, University of Reading. Association of Researchers in Construction Management, Vol. 1, 268-77.

development is still at the prototyping stage. Ha (1997) has developed a VR-based design co-ordinator that can be used by designers at the early stage. The system has been implemented by integrating VR, databases and video conferencing technologies. The main limitation of this system is the lack in its web-based capabilities. Other work includes that of Stone (1995) and Griffin (1995) on how VR can be used as design tools. Retik (1995) and Lorch(1995) highlight the importance of VR as animation and simulation tools. Alshawi & Faraj (1995) suggest that VR should be used as the interface for 3D models and databases. Finally, work is underway at Loughborough University to evaluate the benefits of using VR (Whyte 1998). This paper builds on the work done by the previous researchers in order to develop a VR tool which can be used as a combination of visualisation, animation and simulation and as an interface for an object oriented integrated database which can support the activities of design, time planning and cost estimating performed within construction projects. The work described in this paper has been developed at Salford University as part of the OSCON (Open Systems for Construction) project. The prototype demonstrator presented in this paper has been developed through a series of workshops attended by the industrial collaborators of the research project who specified the requirements of such a prototype

INTEGRATED DATABASES

Integrated project databases are amongst the most promising technologies for the construction industry. The recommendations of “Construct IT bridging the gap” regarding the development of integrated databases is just one example of the relevance of this important area to the construction industry. Object orientation offers superior capabilities in this area, particularly in terms of information abstraction. Establishing an integrated project database is a skilled task that is currently poorly supported by technology. As construction firms are becoming more reliant on information technology and computerised records, the efficient and effective utilisation of their data will become more crucial to their business success. Current relational database technology can provide efficient access to structured data through various query languages. However, this technology falls short of the facilities provided by object oriented. In order to demonstrate how such an integrated approach can benefit construction projects, the OSCON team is developing a suite of software applications, e.g. CAD application, cost estimating and planning, wrapper software for CA-Superproject®, which will actively share construction information via a central object-oriented project database. In addition to these applications, two optional utilities have been added, a Project Manager and Virtual Reality (VR) interface. The project manager can be used to manage communication between different participants of the construction project and to monitor the progress of different construction processes. The VR interface allows the user to visualise and manipulate the design produced by the CAD components in 3D environment. In addition, planning and costing information can be viewed and retrieved in the VR environment. The applications are being developed on PCs running under Microsoft Windows NT and are implemented in Microsoft Visual C++. The database is implemented using ObjectStore® OODBMS in conjunction with Object Engineering Workbench (OEW®) modelling software. OEW is useful for generating OSCON models and the associated code in C++ (Aouad *et al.* 1997a). Figure 1 shows a schematic representation of the architecture of the system.

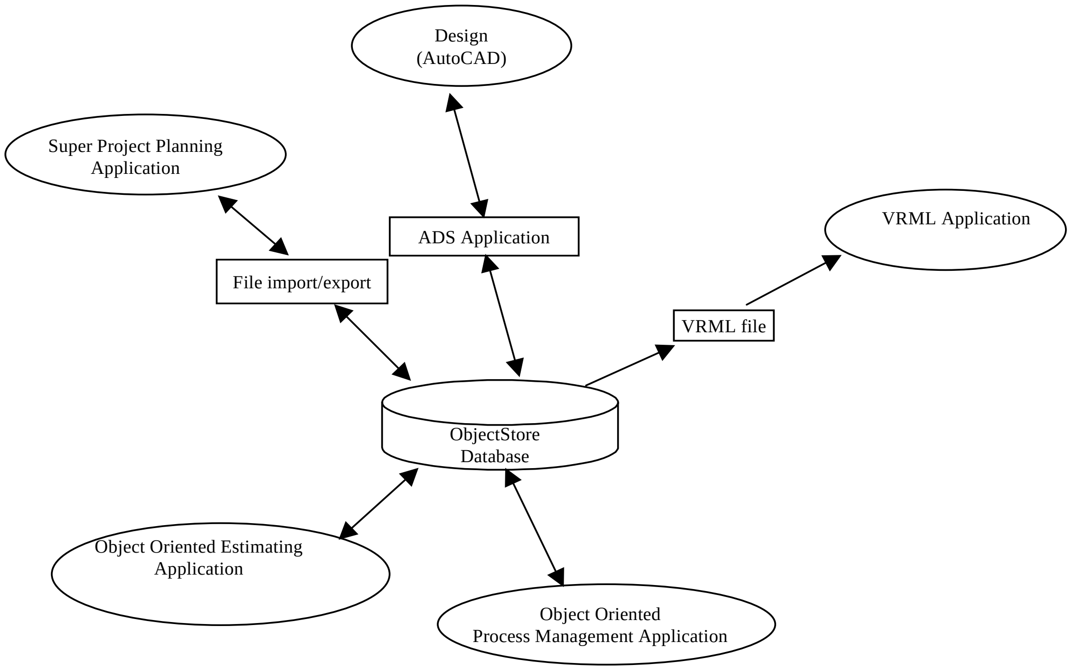


Figure 1: the overall architecture of the system

THE VIRTUAL REALITY INTERFACE

The emphasis of this paper is on the use of VR to support the integration of design and construction management information. A major problem associated with this is the shear information involved and the complexity of storing such information. Traditionally, the user interface provided within databases has been used to query information stored in these databases. This has proven to be difficult in browsing through the many records of instances of entities developed within the scope of a certain construction application, particularly the design and construction management information. One way of browsing and querying is through the use of VR interfaces. It is a more natural way of interfacing with information as the user can visually identify the objects of interests and retrieve information about them using the VR interface. This approach was adopted by OSCON in order to respond to the user needs for a user-friendlier environment. Within OSCON, the user can navigate through the VR model and identify elements by clicking on them. Information is then obtained about the specific objects depending on the view or requirements of a particular participant of the construction process. For instance, the designer can retrieve information about the specifications of a cavity wall, the QS can obtain cost information about the same cavity wall, and the time planner queries the model to retrieve information about the duration of building this cavity wall (Aouad et al 1997b). This process will be described in detail in one of the forthcoming sections.

The VR application reads information about the design produced in AutoCAD from the database and displays it in a virtual reality environment. This provides better visualisation using the web-based VRML (Virtual Reality Modelling Language). This utility which is shown in Figure 2, is used as a means of interrogating the integrated database remotely over the Internet in order to allow practitioners within the construction industry better access to the OSCON integrated database.

The potentials of using virtual reality as an interface for an integrated project database using the World Wide Web are tremendous. Ease of access and real-time integration can be achieved. VRML is one of the newest open technologies on the web. It allows the creation of 3D views and worlds that can be explored in real time. Technologies are now available which can be used to this end. The Internet and its facilities should be exploited for the benefits of better management and retrieval of construction information.

The Virtual Reality Modelling Language (VRML) is a developing standard for describing interactive three-dimensional scenes developed across the Internet (Ames 1996). A VRML browser is needed to load VRML files that allow users to navigate through VRML worlds. The VRML file is a textual description of the VRML World. It contains nodes that describe shapes and their properties. VRML's four primitive shapes include cube, sphere, cone and cylinder. Figure 2 illustrates the overall architecture of the link between a VRML viewer and an integrated database.

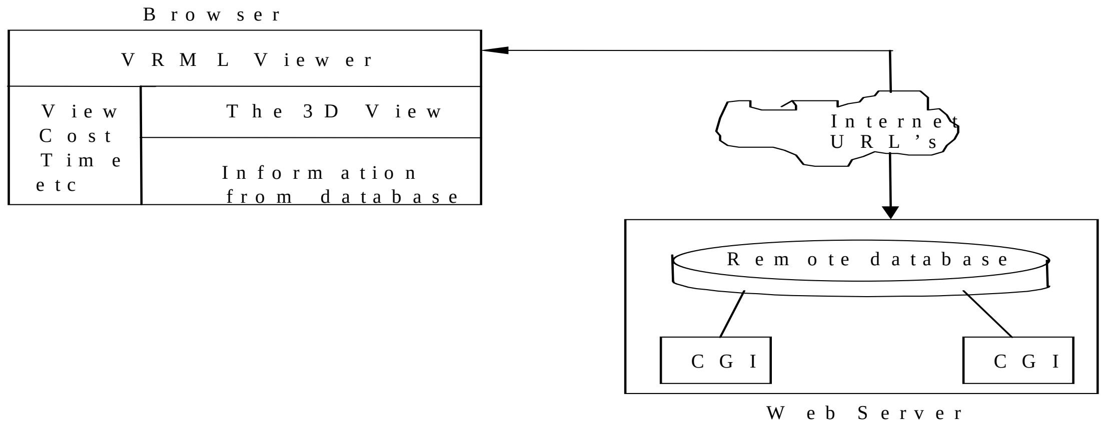


Figure 2: The VRML prototype architecture (Aouad et al 1997b)

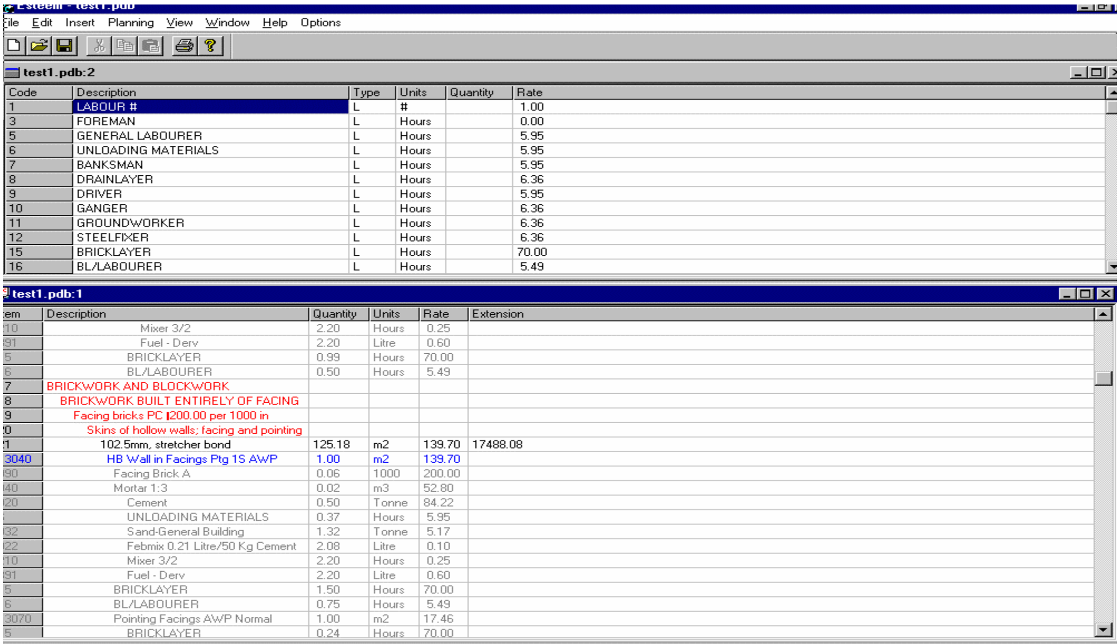
The above figure shows diagrammatically how information is accessed from the database. The VRML standard allows links between different worlds to be established on the web. This puts the entire Internet at the fingertips of its users. Links are anchored to specific objects such as walls, beams, etc. By clicking on an anchored object you request information from other worlds using a URL (Universal Resource Locator) that specifies the address of a file on the web. Worlds loaded from the Internet are delivered by the web server running on the remote host at the remote Internet site. In our case, the URL specifies a CGI script that is a c++ program to run on the remote host under the control of the web server. The CGI program returns information about objects being queried in the VRML browser.

VR AND THE CAD APPLICATION

The CAD application allows the user to create and manipulate architectural components of a building. The components are stored as instances of classes in the architectural design model. This is achieved through an AutoCAD Application Development System (ADS) program which is loaded by a user of an AutoCAD session which allows objects stored in the object oriented database to display themselves in AutoCAD. The CAD package allows creation and manipulation of building elements such as foundations, walls, windows, doors, floors, stairs and roofs. Because the CAD package stores its data in the shared project database this will be immediately available to other packages and other disciplines via the core integration model (Aouad et al 1997c, Aouad 1997d). The VRML application reads information about design stored in the database and displays it in the VR environment. This allows full access to the design model in a real time interactive environment remotely over the Internet. This facility assists designers working across remote sites by allowing them to view the design and interact with it.

VR AND THE COST ESTIMATING APPLICATION

A cost-estimating tool has been developed using Microsoft Visual C++. This tool allows costs to be associated with the building components produced via the CAD package. The cost-estimating tool allows the production of bills of quantities and entry of unit rates. The cost information stored in the central database can be viewed in the VR environment using the CGI programs mentioned before. In a fully interactive environment, the user can access information from the database through the building model. In addition, the model can be used to visually inspect the correctness of cost information in the database. The research team has defined a colour map that shows the building components in various colours depending on the normally expected unit rate for an element. For instance, doors are expected to appear in certain colour for a range of unit rates. If they appear otherwise, this signals that there may some inconsistencies in the cost model. The estimator could then check specific records in the database. This approach which has been adopted as part of the integrated model may lead to many new areas of virtual cost estimation. One area that may benefit significantly is elemental cost estimating whereby costly elements appear on the computer screen in a certain colour ensuring that enough attention is paid to these elements. The figure shown below illustrates the automatic generation of cost estimates from the database using information from the design model. Quantity take-offs are performed automatically and the rates for work items are determined by the model using a company's library of work items and resources. The same information can then displayed in the VR model. Figure 3 shows an output from the estimating application.



Code	Description	Type	Units	Quantity	Rate
1	LABOUR #	L	#		1.00
3	FOREMAN	L	Hours		0.00
5	GENERAL LABOURER	L	Hours		5.95
6	UNLOADING MATERIALS	L	Hours		5.95
7	BANKSMAN	L	Hours		5.95
8	DRAINLAYER	L	Hours		6.36
9	DRIVER	L	Hours		5.95
10	GANGER	L	Hours		6.36
11	GROUNDWORKER	L	Hours		6.36
12	STEELFIXER	L	Hours		6.36
15	BRICKLAYER	L	Hours		70.00
16	BL/LABOURER	L	Hours		5.49

em	Description	Quantity	Units	Rate	Extension
10	Mixer 3/2	2.20	Hours	0.25	
91	Fuel - Derv	2.20	Litre	0.60	
5	BRICKLAYER	0.99	Hours	70.00	
6	BL/LABOURER	0.50	Hours	5.49	
7	BRICKWORK AND BLOCKWORK				
8	BRICKWORK BUILT ENTIRELY OF FACING				
9	Facing bricks PC 200.00 per 1000 in				
0	Skins of hollow walls; facing and pointing				
1	102.5mm, stretcher bond	125.18	m2	139.70	17488.08
3040	HB Wall in Facings Ptg 1S AWP	1.00	m2	139.70	
90	Facing Brick A	0.06	1000	200.00	
40	Mortar 1:3	0.02	m3	52.80	
20	Cement	0.50	Tonne	84.22	
	UNLOADING MATERIALS	0.37	Hours	5.95	
32	Sand-General Building	1.32	Tonne	5.17	
22	Febmix 0.21 Litre/50 Kg Cement	2.08	Litre	0.10	
10	Mixer 3/2	2.20	Hours	0.25	
91	Fuel - Derv	2.20	Litre	0.60	
5	BRICKLAYER	1.50	Hours	70.00	
6	BL/LABOURER	0.75	Hours	5.49	
3070	Pointing Facings AWP Normal	1.00	m2	17.46	
5	BRICKLAYER	0.24	Hours	70.00	

Figure 3: Cost estimation

VR AND THE PROJECT PLANNING APPLICATION

In order to illustrate that a legacy application which supports construction planning and scheduling can be used, a CA-Superproject translator has been developed to provide a way of exporting and importing files between CA-Superproject and the project database. CA-Superproject is a general-purpose project planning package produced by Computer Associates Ltd. A wrapper has been built around the CA-SuperProject project-planning package. The wrapper will allow the user to import information from the database, work on it in superproject and then export it back to the database. This procedure is illustrated below.

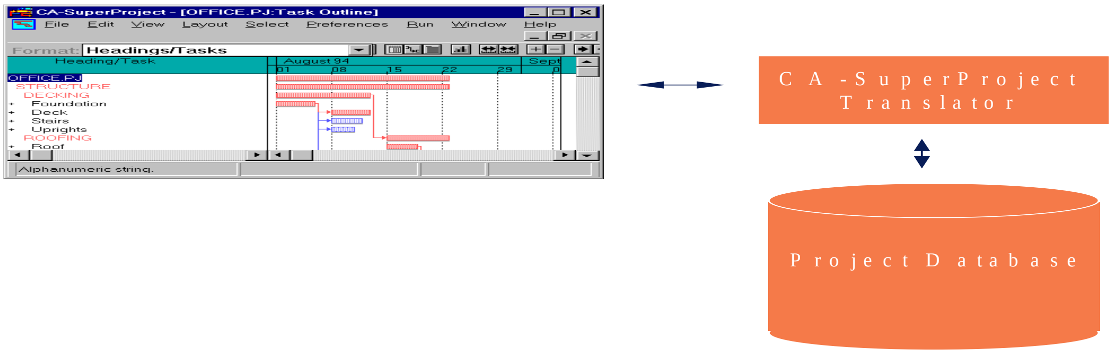


Figure 4: The planning translator

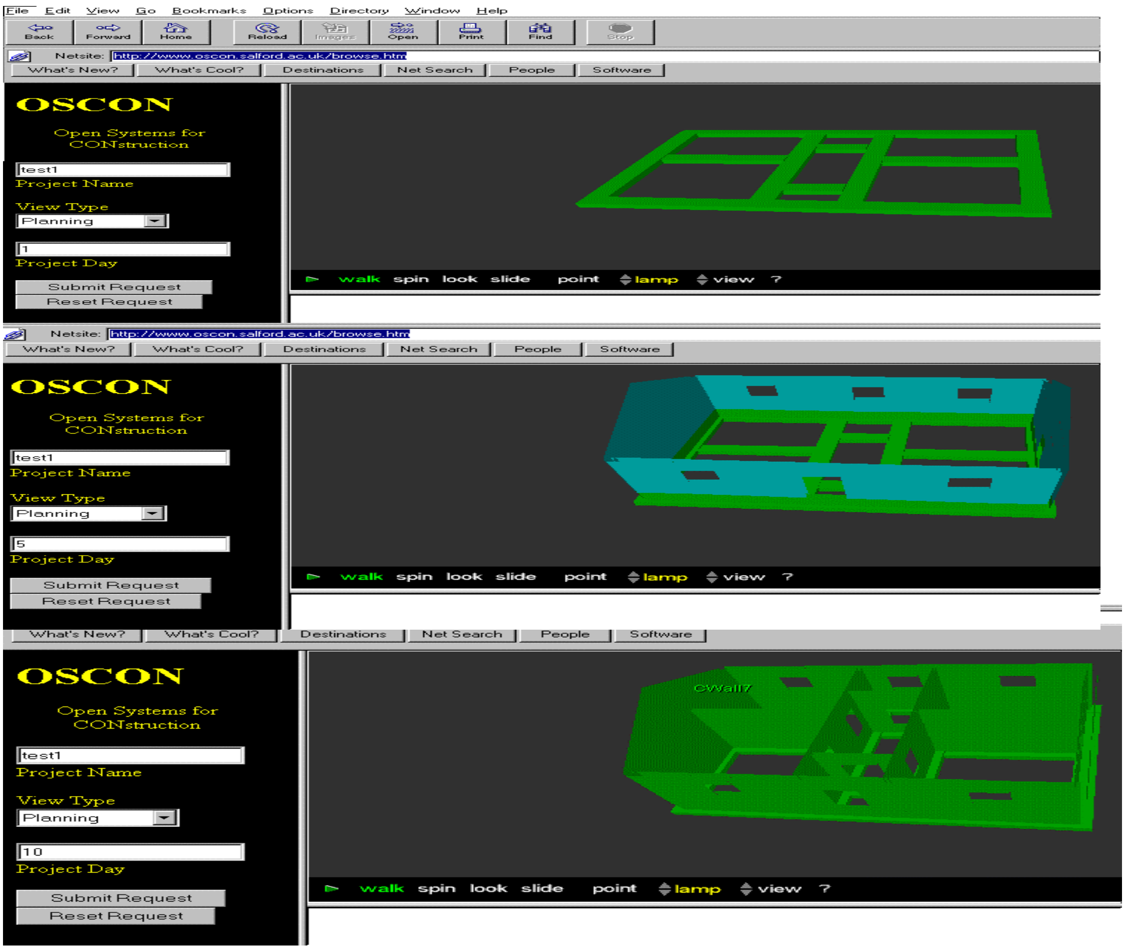


Figure 5: Planning in the VRML interface

The project planning information is then read from the database and displayed in the VR environment. As construction tasks stored in the database contain information about durations, start dates, end dates and dependencies, this will allow the VR environment to be used as the medium for checking the status of construction plans. Figure below shows the status of construction plans in VR on days 1, 5 and 10. This will allow a better access to planning information through the interactive capabilities of VR. CGI programs have been used to retrieve information from the remote database to be displayed in the VRML interface, which is web-based.

HOW THE SYSTEM WORKS

The user starts running the OSCON prototypes by interfacing with the root user interface shown below:

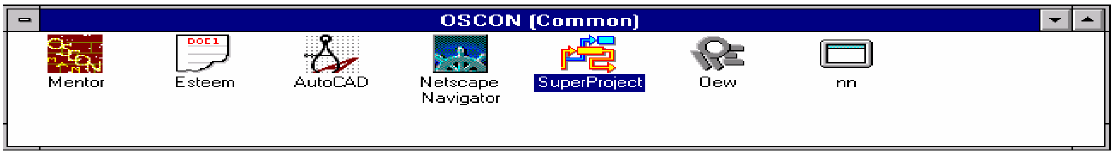


Figure 6: The overall OSCON interface

The mentor program starts the OSCON project manager. This will allow us to create a shared database within object store and to manage the communications between applications (see figure 7).

Figure 7: The process management interface

Within the Esteem interface, we can down load a standard library of resources, activities and work items. These are company's databases. Next and from within the AutoCAD interface, an ADS application can be downloaded which creates the OSCON design interface. The information is shared in the same database as that of the project manager and the estimator and planner. Figure 8 shows a default building created from the central database.

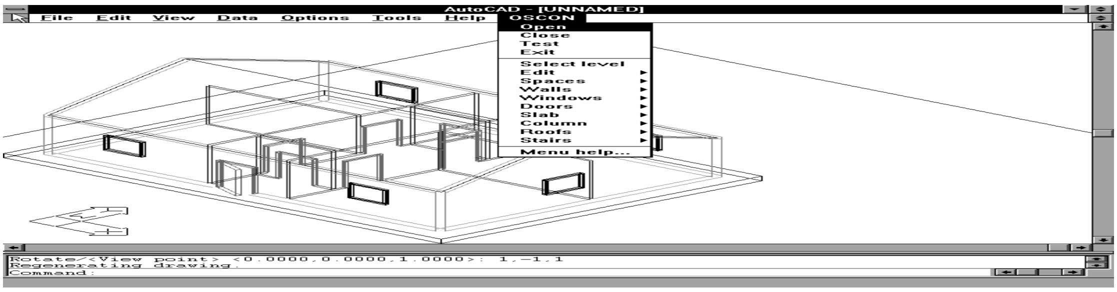
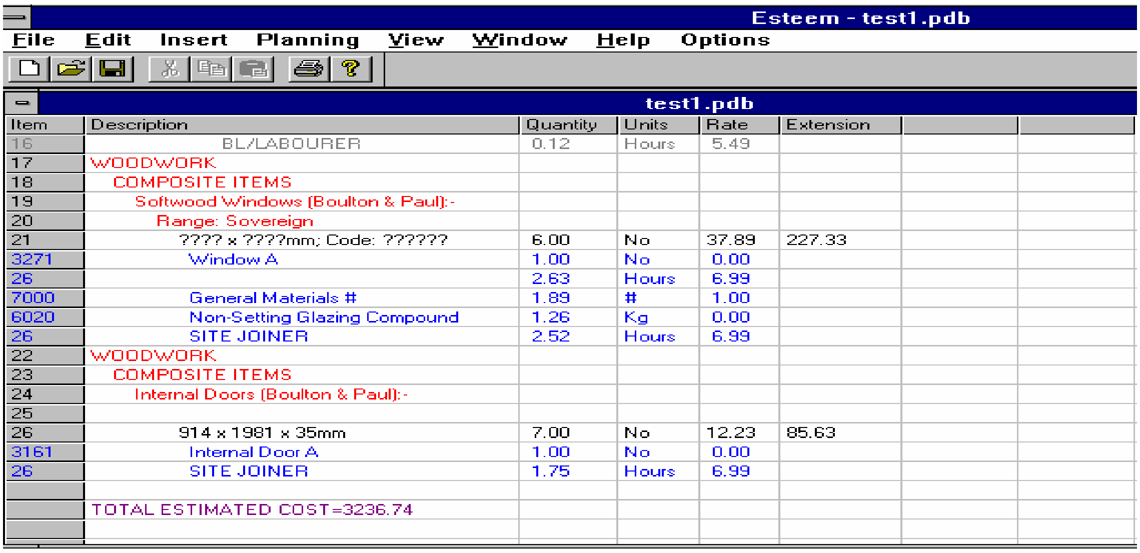


Figure 8: A building design shown in AutoCAD

From within the Esteem estimating interface, the work items associated with the design are created automatically. This includes quantities, rates and total cost (see Figure 9)



Esteem - test1.pdb

File Edit Insert Planning View Window Help Options

test1.pdb

Item	Description	Quantity	Units	Rate	Extension
16	BL/LABOURER	0.12	Hours	5.49	
17	WOODWORK				
18	COMPOSITE ITEMS				
19	Softwood Windows (Boulton & Paul):-				
20	Range: Sovereign				
21	???? x ????mm; Code: ??????	6.00	No	37.89	227.33
3271	Window A	1.00	No	0.00	
26		2.63	Hours	6.99	
7000	General Materials #	1.89	#	1.00	
6020	Non-Setting Glazing Compound	1.26	Kg	0.00	
26	SITE JOINER	2.52	Hours	6.99	
22	WOODWORK				
23	COMPOSITE ITEMS				
24	Internal Doors (Boulton & Paul):-				
25					
26	914 x 1981 x 35mm	7.00	No	12.23	85.63
3161	Internal Door A	1.00	No	0.00	
26	SITE JOINER	1.75	Hours	6.99	
	TOTAL ESTIMATED COST=3236.74				

Figure 9: Cost estimates shown in Esteem

Through Netscape navigator and using 3D-live plug-in, a VRML browser can be launched which will allow full interaction with the building in real time. Figure 10 shows the same design created by AutoCAD viewed in VRML.

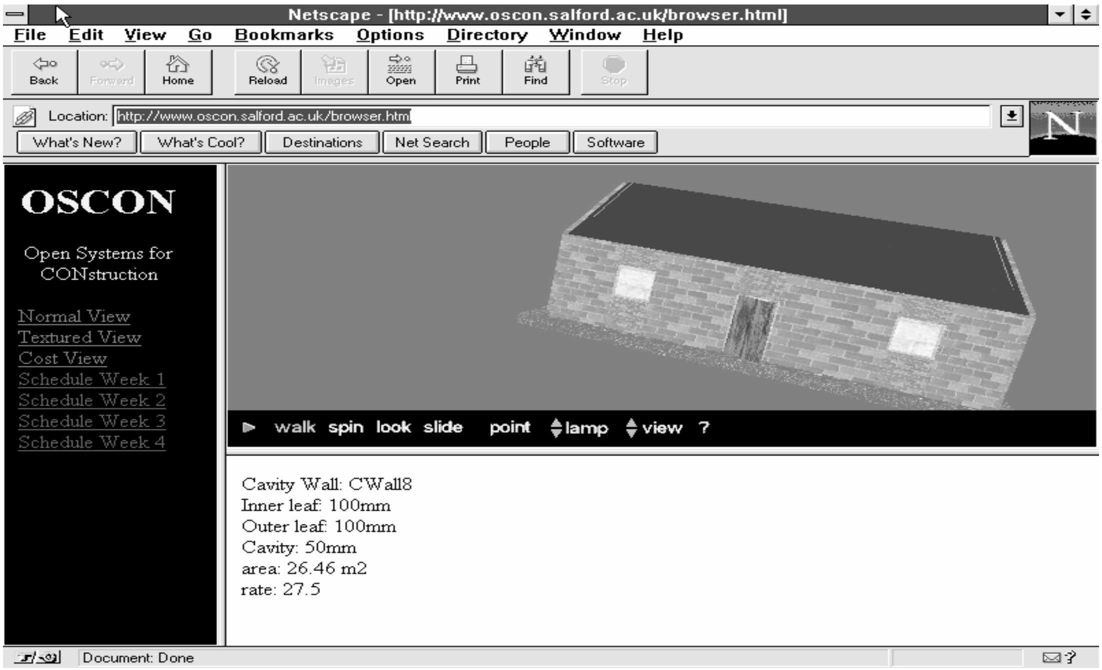


Figure 10: A design in VRML with cost data

In Figure 10, any view can then be selected from the left hand side frame to interact with the model. The figure above illustrates how cost information is extracted from the database is displayed in VR.

Within the superproject application and using import/export facilities, the construction activities are linked in order to determine the critical path. The planning information can then be viewed in VRML using the CGI programs described earlier.

The developed prototype has been demonstrated live to more than fifty large UK firms (clients, designers and contractors). The feedback has been positive in terms of the technological capabilities. However, concerns have been expressed on whether the current process supports the technology described in this paper. Current research is underway in order to address this problem.

CONCLUSIONS

This paper presented an approach to the integration of design and construction information using object orientation, integrated databases and VR. This paper demonstrated that VRML provides a good interface for construction information. Designers, planners and estimators alike can have access to this interface. In addition, the developed prototype illustrates that the technology is ready to be adopted by the industry if information is to be integrated efficiently. However, working practices and culture need to change if this technology is to survive. It is becoming vital to consider integration through technology, process and cultural and human issues. This will be the subject of further research to be conducted in this important area. In addition, the use of VR within the context of VRML and as an aid to support the integration of design, planning, costing and other information in support of the construction process needs to be assessed using real life projects, particularly at the very early stages of a construction project.

ACKNOWLEDGEMENTS

The authors would like to thank the members of the OSCON steering committee for their kind contribution. The work presented here is supported by the Department of Environment, Transport and the Regions which is highly acknowledged.

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